Properties of Colliding Supernova Remnants in a Laboratory Setting: Implications for Triggered Star Formation

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The theoretical framework of star formation still underestimates the observed astronomical rates. New stars form within giant molecular clouds (GMCs), which fragment into dense clumps under the combined influence of gravity, magnetic fields, radiation, and turbulence (C. F. McKee & E. C. Ostriker, 2007). When these clumps are stable, their collapse can be externally triggered by nearby astrophysical events, such as protostellar jets or supernova explosions. In the case of the Elephant Trunk Nebula, such external triggering has been estimated to contribute 14–25% of the total star formation rate (K. V. Getman et al., 2012). The development of advanced experimental techniques has made it possible to replicate astrophysical processes in laboratory settings using pulsed power systems, such as high-energy laser facilities (B. A. Remington et al., 2006). This approach is supported by scaling laws, which demonstrate the similarity between astrophysical and laboratory phenomena (É. Falize et al., 2011). Laboratory experiments have been used to investigate external triggering in various astrophysical contexts, including protostellar jets (M. Fontaine et al., 2025) and supernova remnants (SNRs). Recent laser experiments successfully reproduced two key configurations: the interaction region formed by the collision of two SNRs (B. Albertazzi et al., 2020) and the impact of an SNR on a dense clump (B. Albertazzi et al., 2022).

In this study, these configurations were further investigated through numerical simulations using the 3D radiation hydrodynamics code TROLL (E. Lefebvre et al., 2018), providing deeper insights into the underlying physical processes. The interaction region of two colliding SNRs exhibits a 20% increase in temperature, a doubling of density, and the development of vorticity—all of which were accurately reproduced in the simulations. In a dense environment, these properties enhance fragmentation. Furthermore, when an SNR interacts with a dense clump, its morphology is altered while simultaneously compressing the clump and increasing its density. We demonstrate that this process reduces the clump's gravitational stability threshold, potentially leading to its collapse.

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